Volcanic Ash Cloud Observations with the DLR-Falcon over Europe during Air Space Closure

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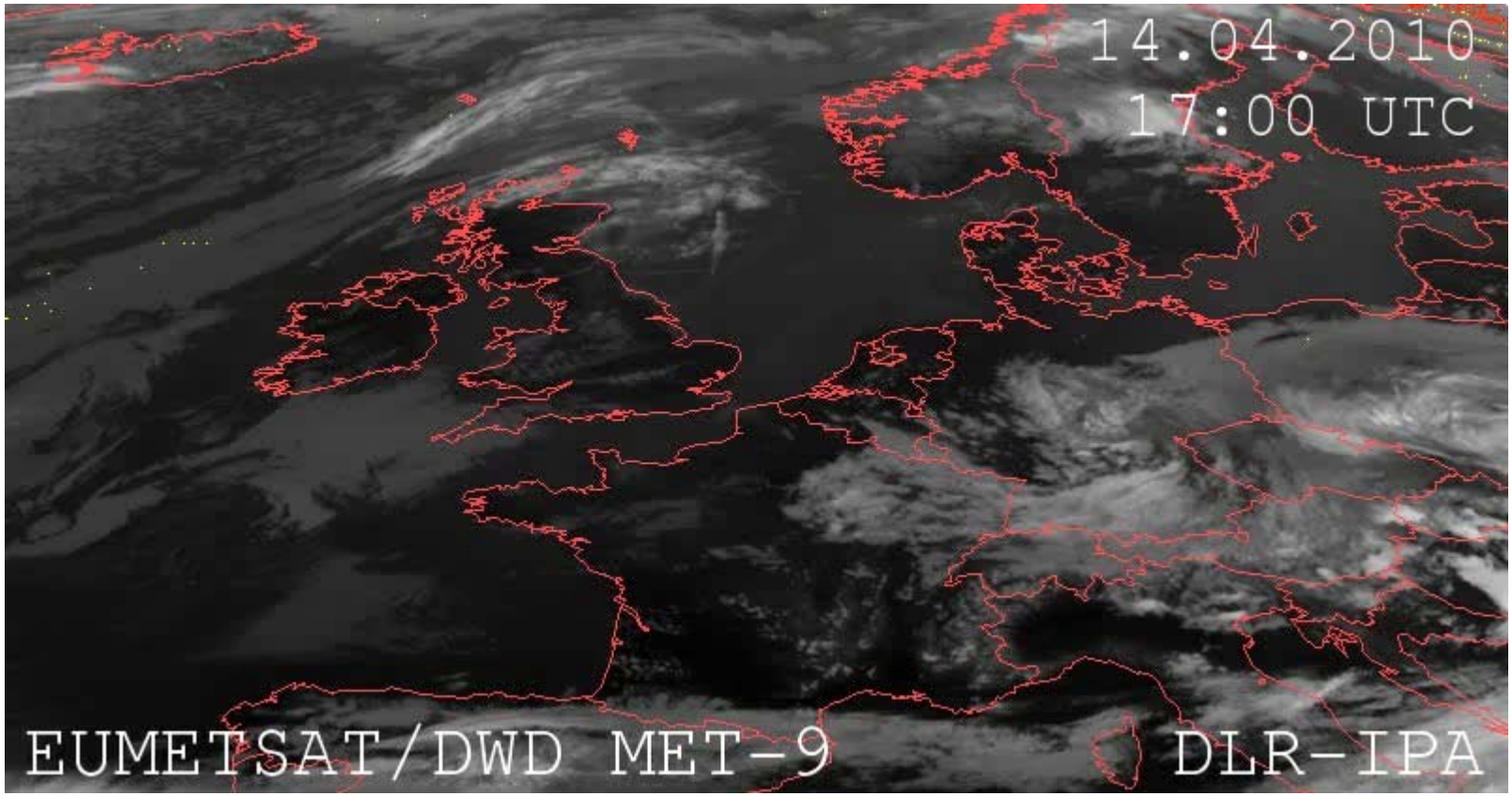
+ many partners (IPA, FB, CNRS-LaMP, TU Darmstadt, IfT Leipzig, LMU München, NILU, Uni. Iceland, DWD, VAAC, DFS, LBA, KNMI, etc.)

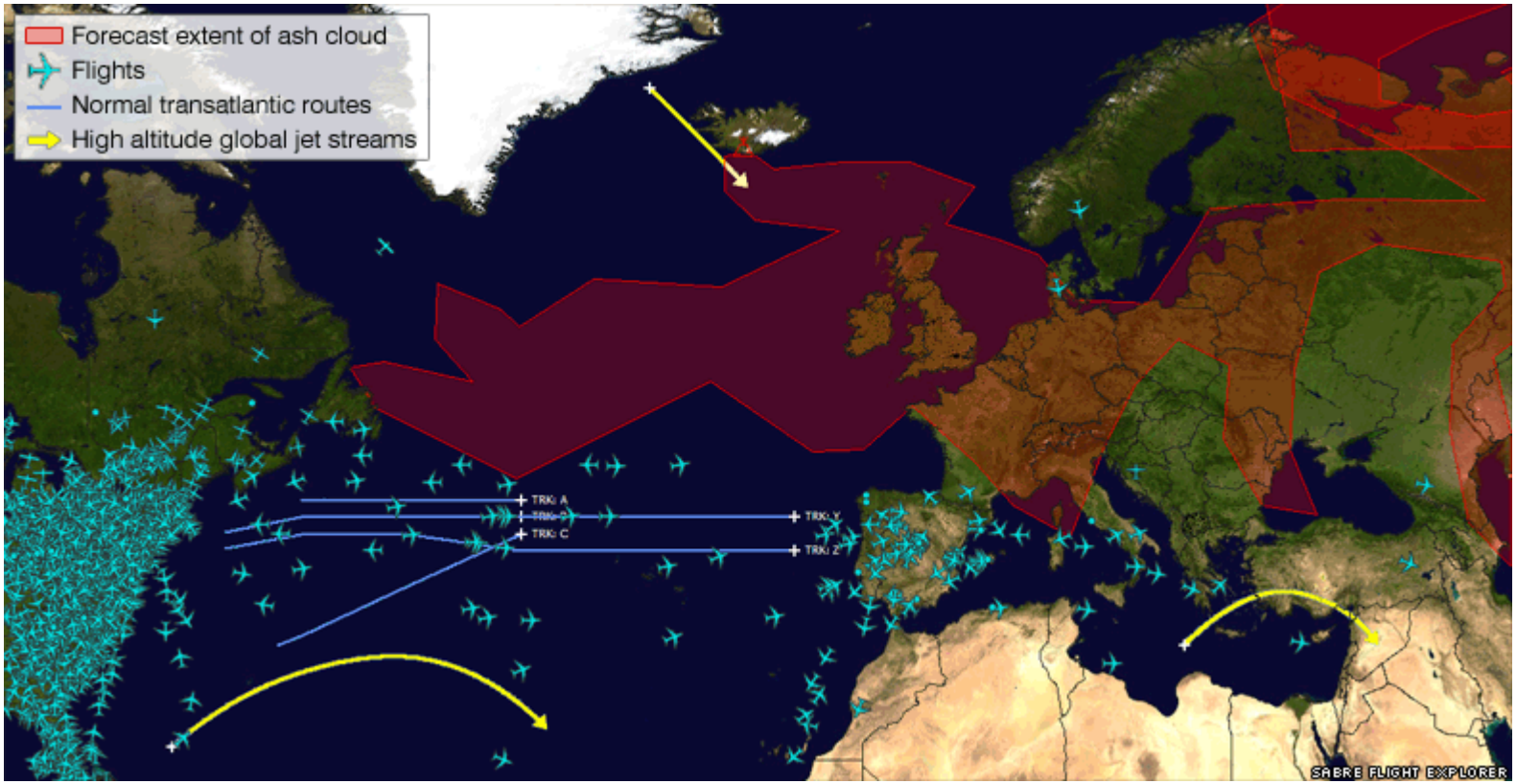
April 14 - April 17, 2010: EUMETSAT-DWD-DLR_IPA



processing and animation by K. Graf, DLR-IPA

19 April, 13:00 UTC - Mid-European airspace closed

DLR-Falcon started at 14:11 UTC



http://www.radarvirtuel.com/

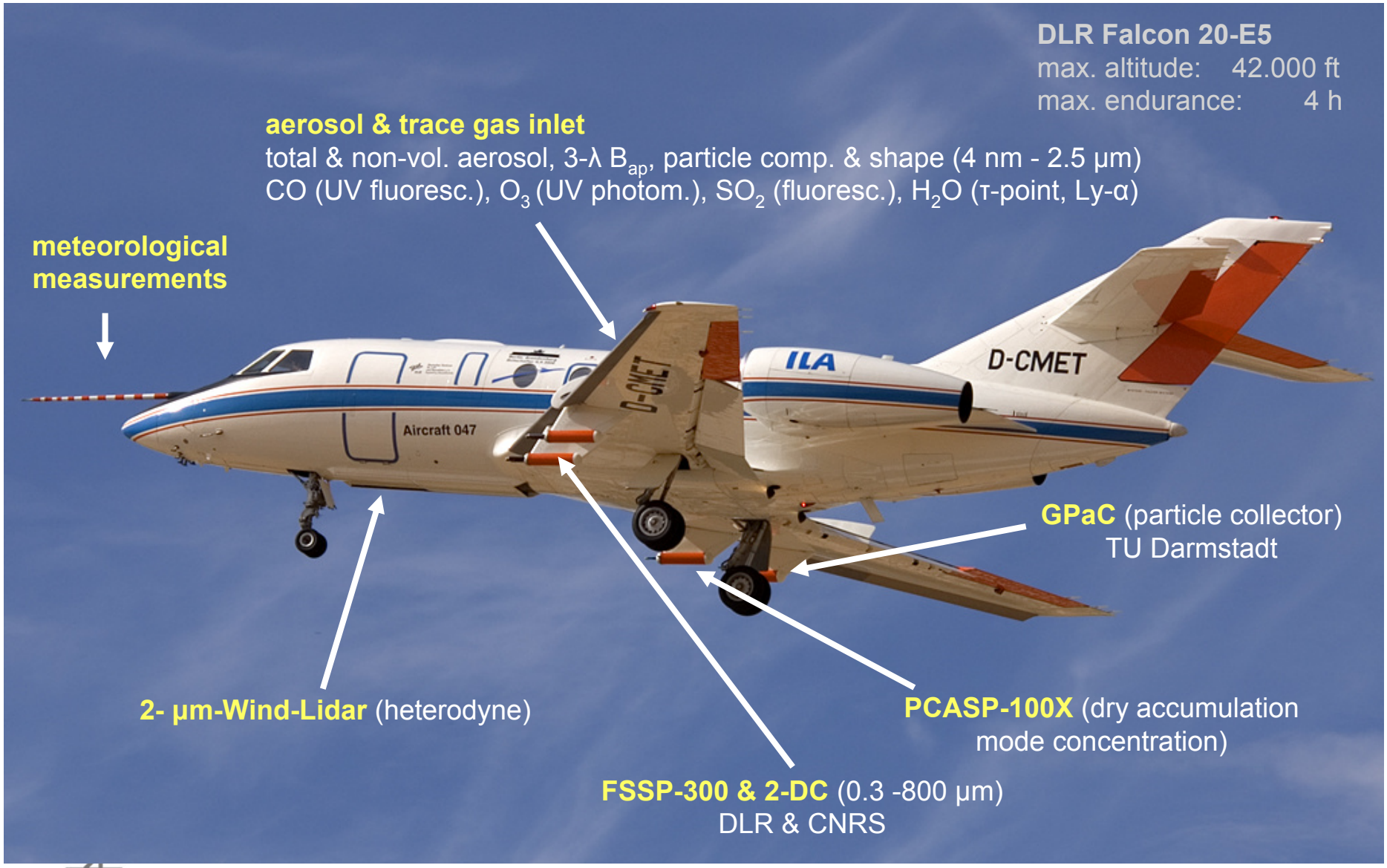
taken from BBC: Iceland volcano in maps

Objectives: Operational & scientific, until May 3

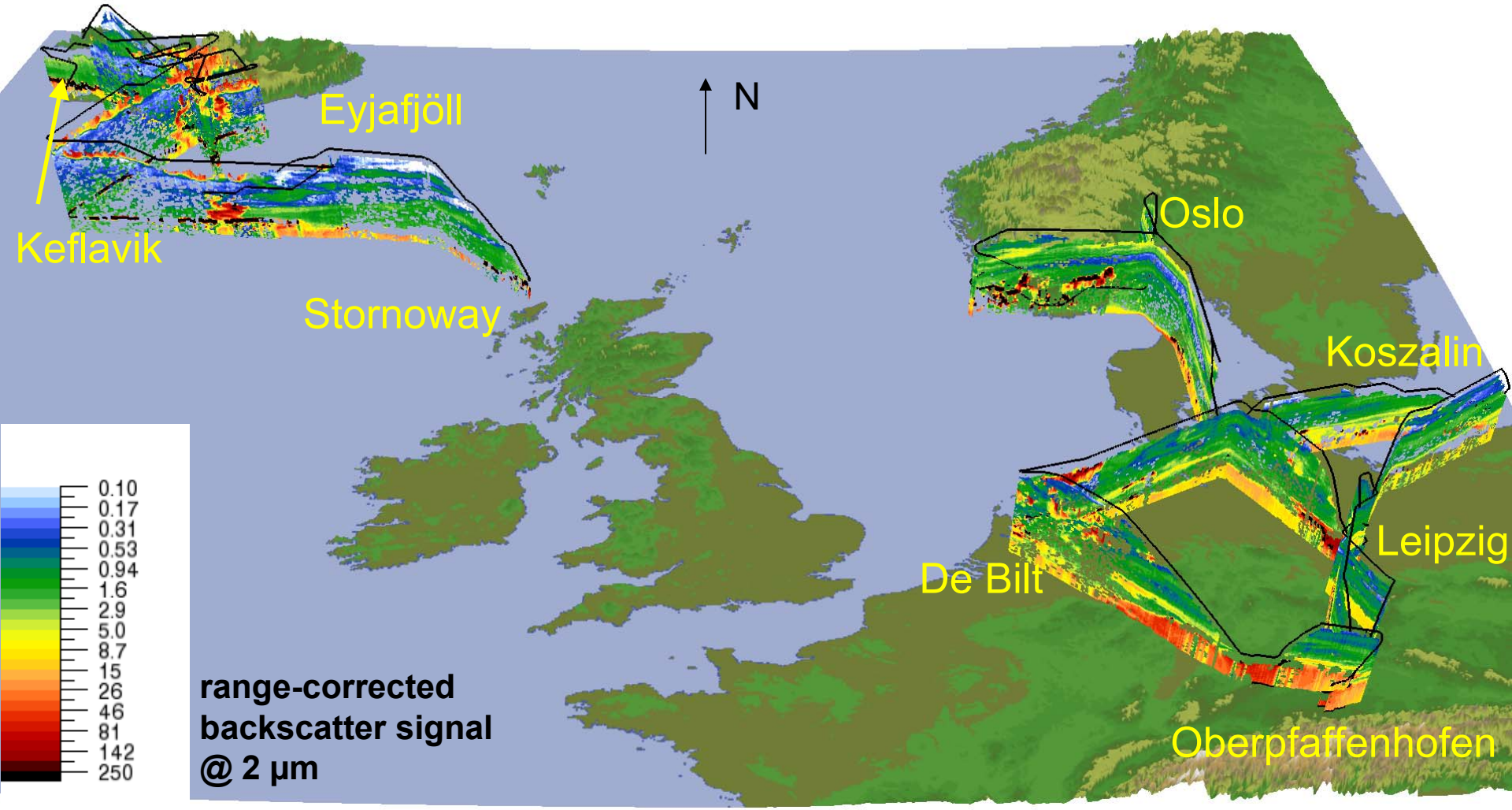
- Closure of airspace justified or exaggerated?
- Quality of forecasts?
- Comparable to Saharan dust?
- What do the lidar instruments see?
- How to convert particle number concentrations to mass concentration?

- Aviation conditions near Iceland
- Volcanic source (mass, particle sizes, chemistry)
- Chemical composition
- Volcanic dynamics

Falcon 20E D-CMET, DLR Oberpfaffenhofen, since 1976



Nine DLR Falcon flights, April 19 - May 2: OP - Iceland



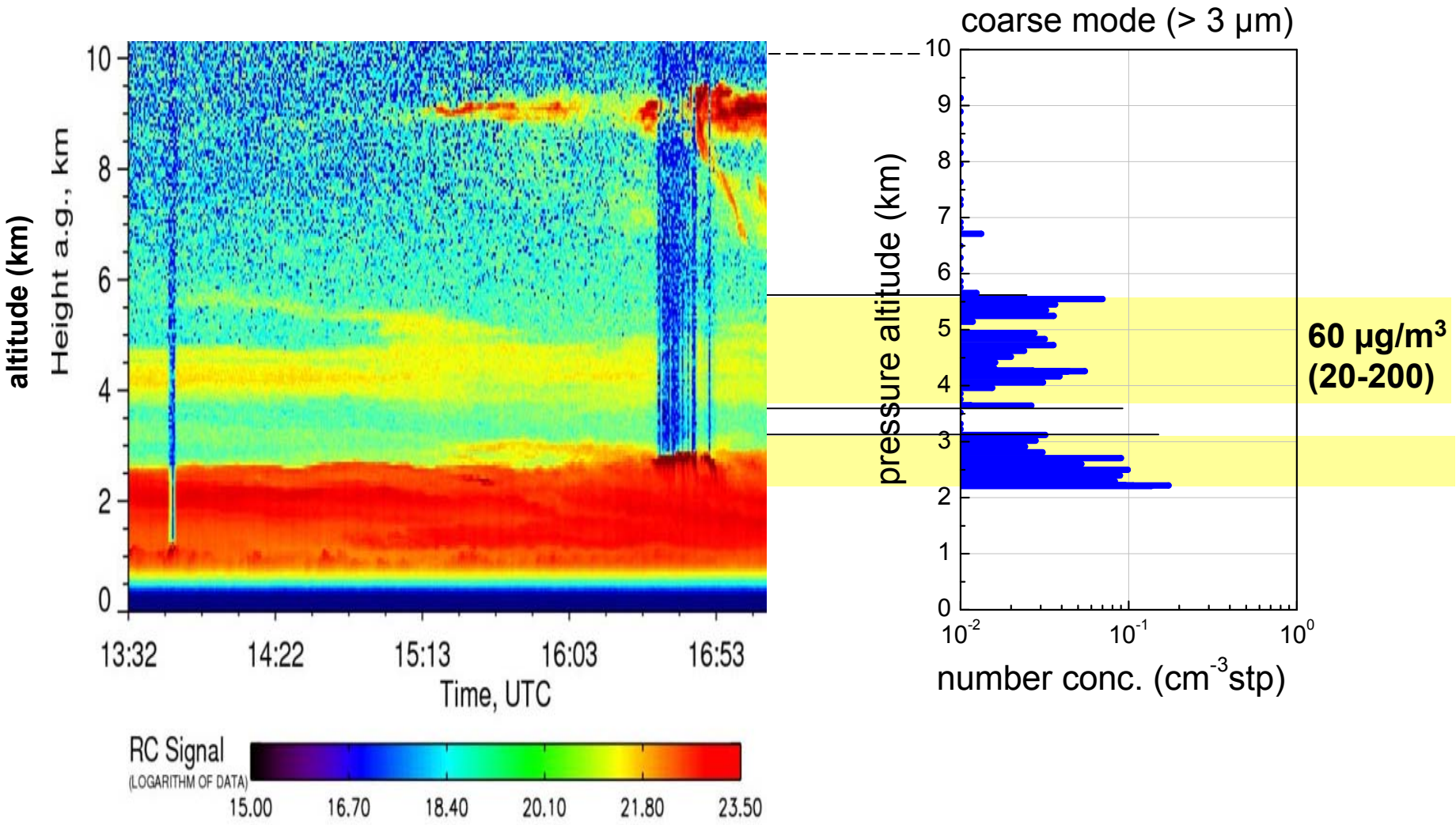
OP –Keflavik: 2700 km

Vulcanic ash layer over Leipzig, April 19, 2010, 15:00 UTC

19 April 2010: Vertical profile measurements over Leipzig

Leipzig lidar

DLR-Falcon, 14:50 - 15:30 UTC



(Ift Leipzig: A. Ansmann, M. Tesche, P. Seifert et al.)

Lagrangian: Iceland - North Atlantic - Ireland - Scotland

(29/04/2010: 50 km distance, arriving in Iceland)

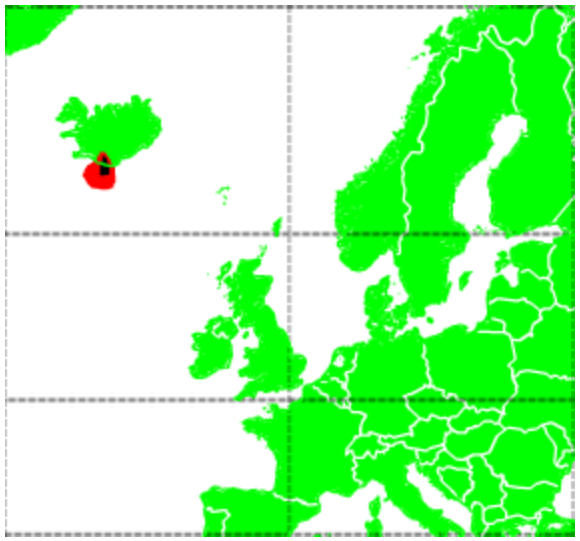
01/05/2010: (8-)200 km distance, 62.5 N, 16.5 W, 11:44 UTC, 1-5 km altitude (age < 3.7 h)

02/05/2010: 450 km distance, 15 W, 60 N, 15:00 UTC, May 2, 2010, age 7 h

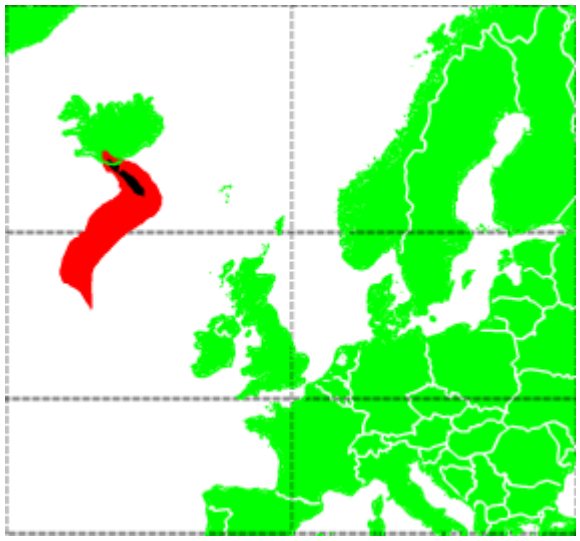
04/05/2010: Mace Head, W, N, ? UTC, May 4, 2010, age about 60 h

05/05/2010: ARSF and FAAM (U Manchester), Scotland airborne, age about 80 h

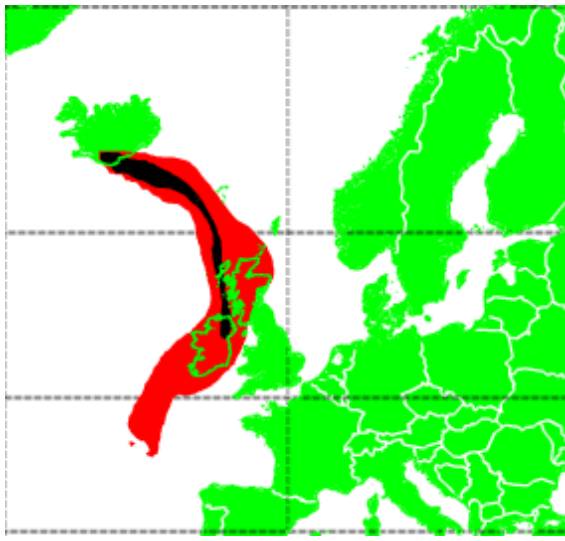
1800 UTC **29/4**

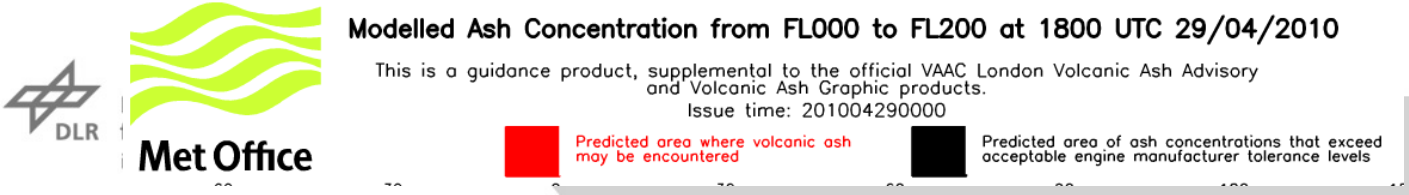


18001200 UTC **01/05**



0600 URC **04/05**/2010





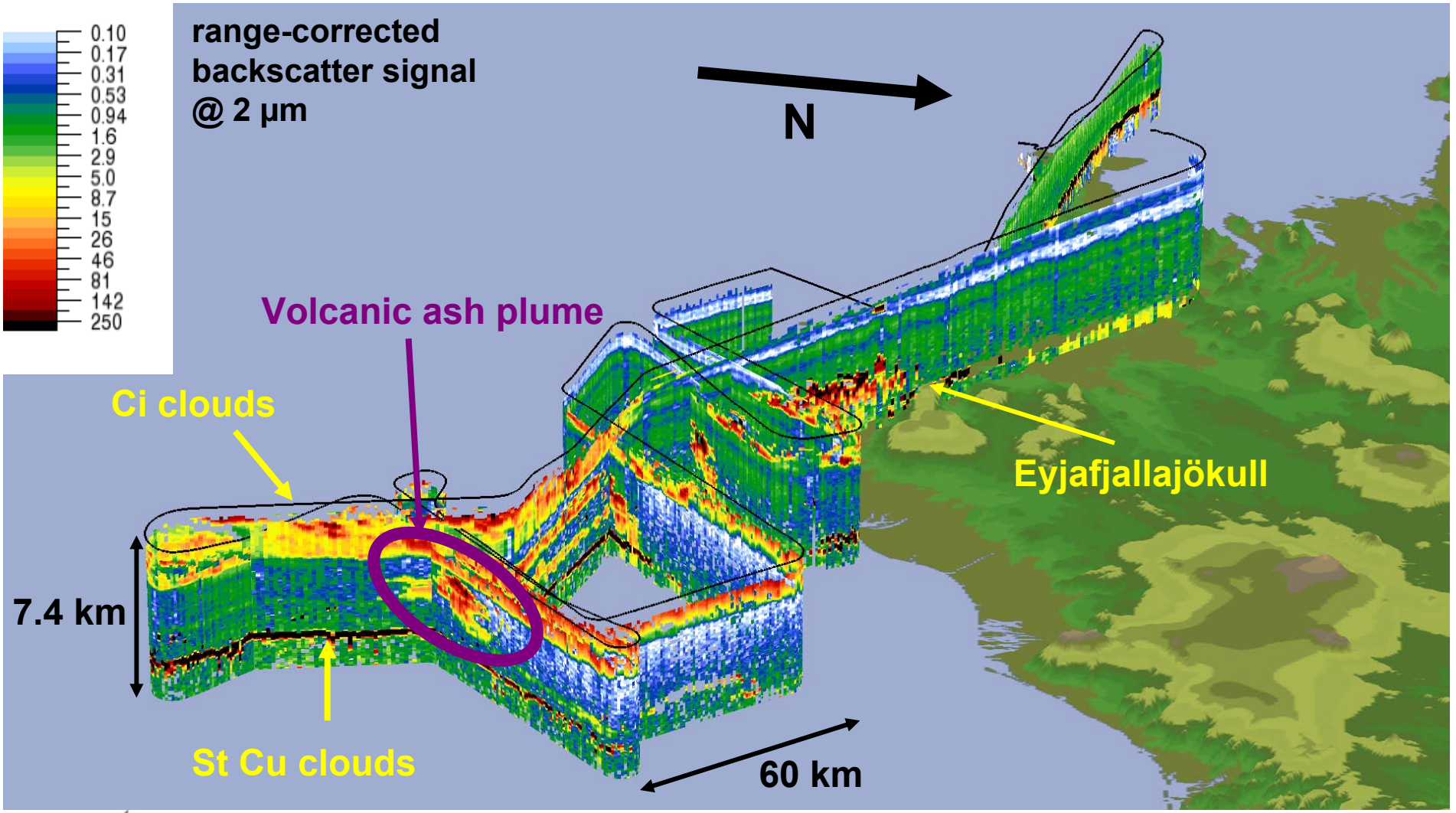
Eyjafjallajökull volcano plume, 29 April, late afternoon time

Eyjafjallajökull volcano plume, May 1, noon time

Eyjafjallajökull volcano plume, May 1, noon time

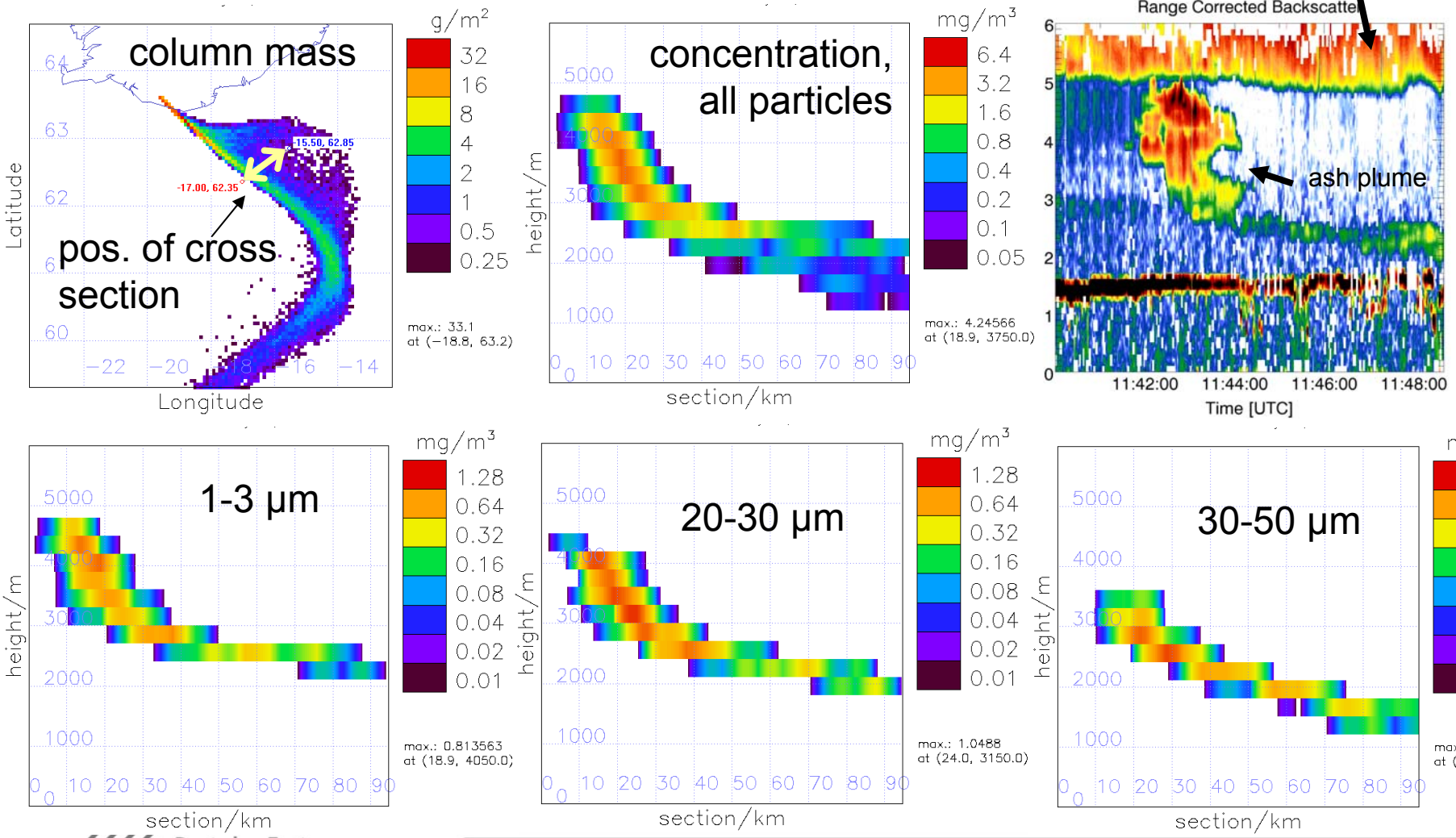
Plume and Keflavik (Iceland) soundings, May 1

plume sounded 1st time

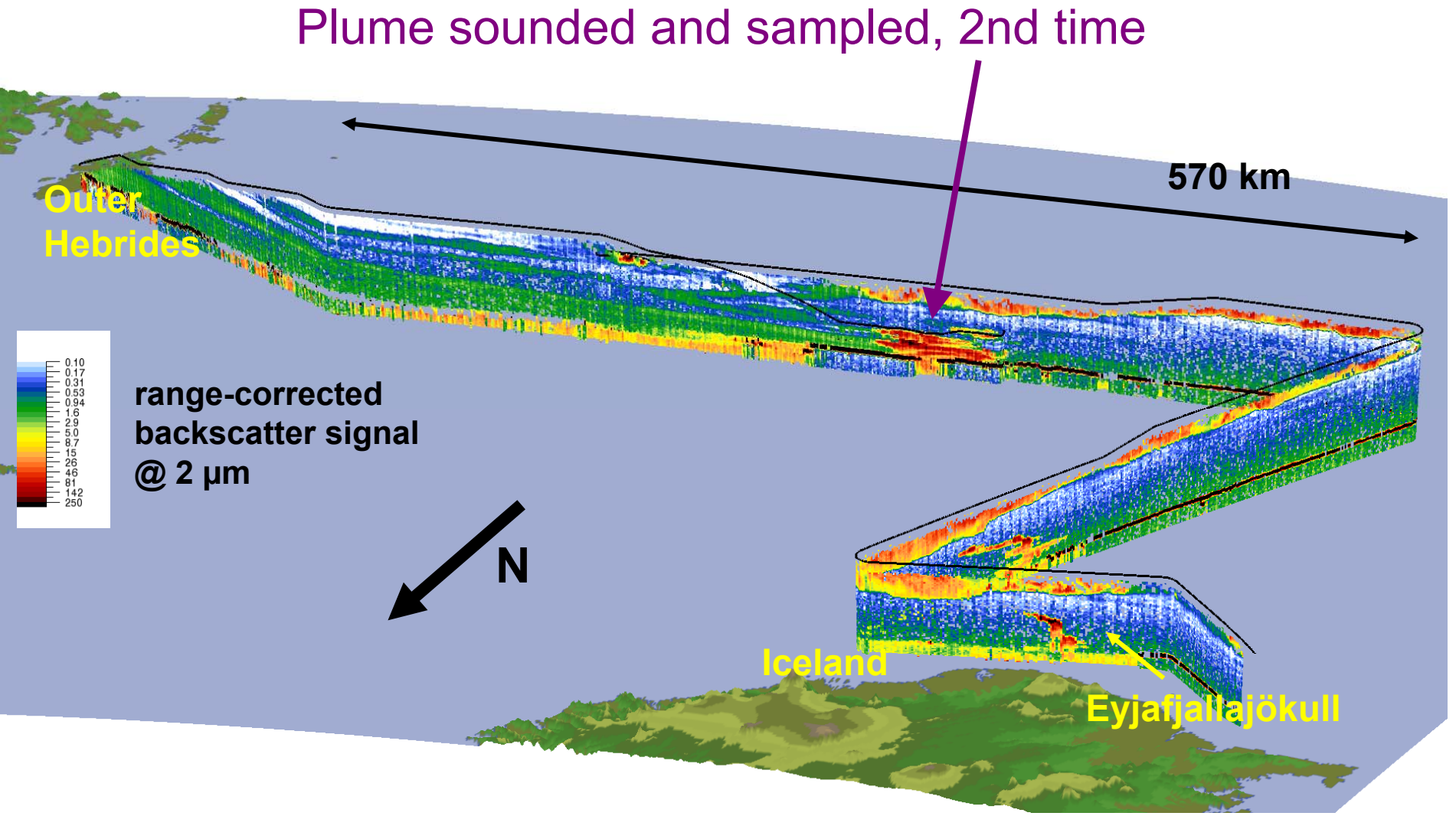


Simulated (HYSPLIT) cross-section of the plume

HYSPLIT model, GDAS 1x1°, 7 particle size classes, line-source from 1.7 km to 4.5 km height a.s.l., mass flux 5000 t/h in 0-50 µm size-range

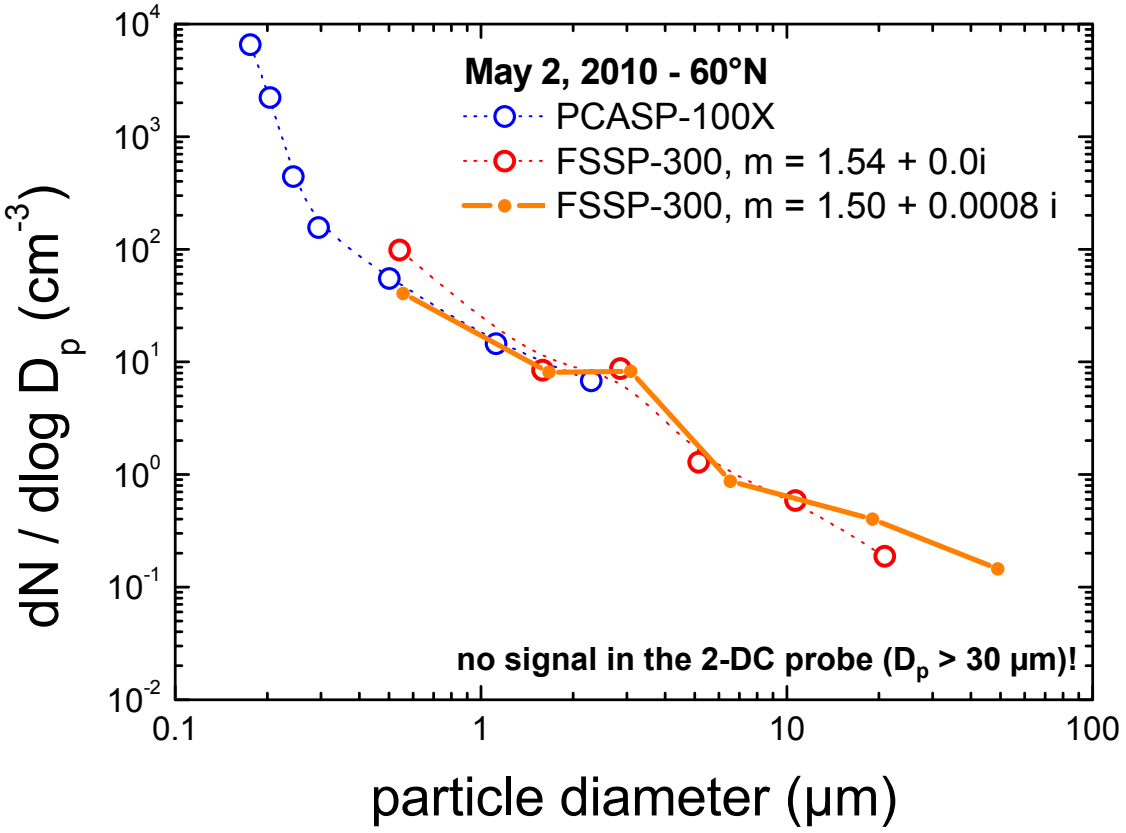


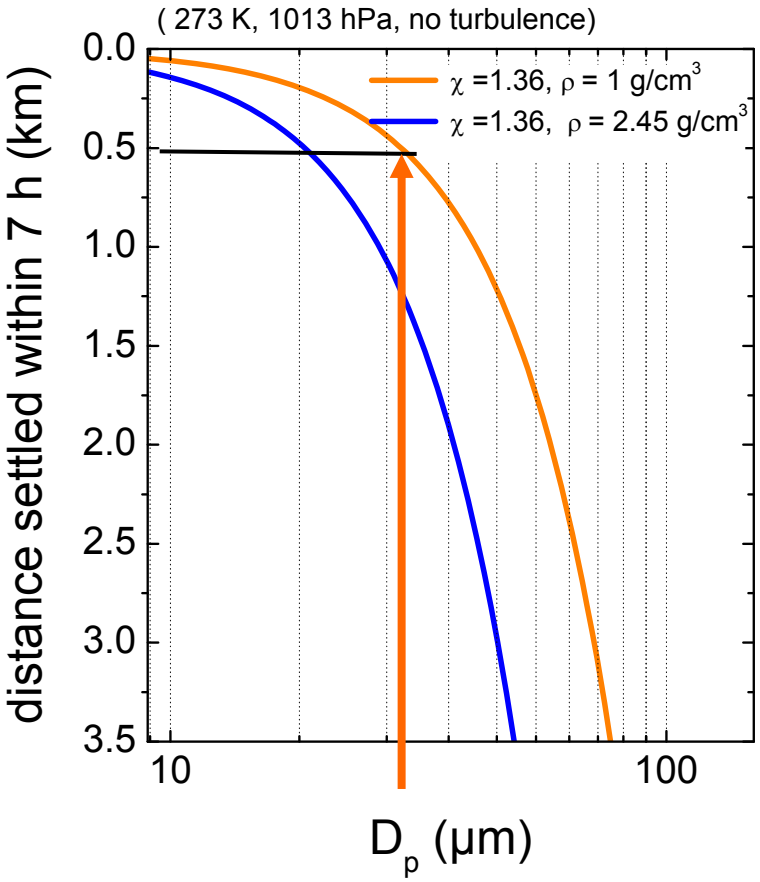
From Keflavik to Stornoway, May 2



North Atlantic (60° N): 15 minutes before flying into the plume

Mass concentrations in the plume over the North Atlantic





m = 1.54 + 0i

PM2.5	10 µg/m³
FSSP-300 "total"	400 µg/m³
D_{eff}	7 µm

m = 1.50 + 0.008i

PM2.5	10 µg/m³
FSSP-300 "total"	3400 µg/m³
D_{eff}	26 µm

...assuming a particle density of 1 g/cm^{-3}

In-situ chemistry in the plume over the North Atlantic

450 km dist., 15 W, 60 N, 15:00 UTC, 02/05/2010, **age 7 h**

3 min in volcanic ash plume, 3400 – 3700 m altitude (FL 110 und 120):

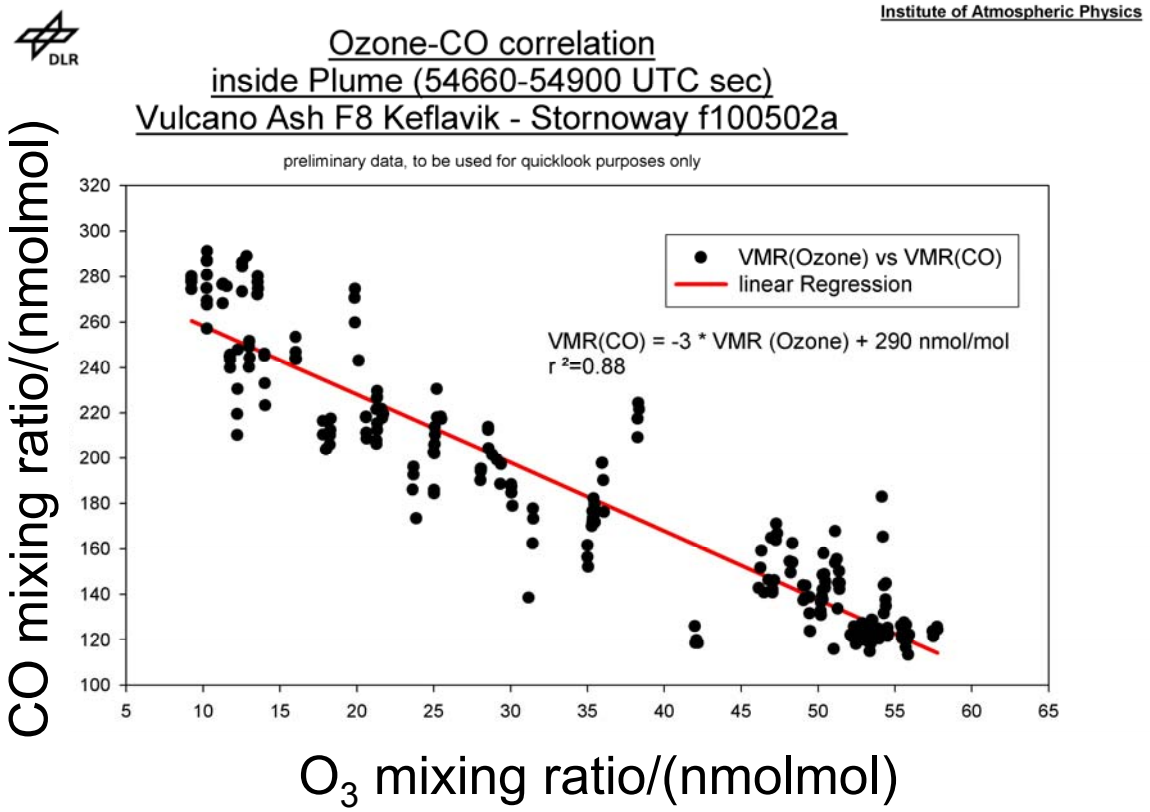
O_3 mixing ratio decrease

CO increase

CO correlates with O_3

SO_2 >150 nmol/mol (outside 0.1 nmol/mol)

H_2O-RH: reduced to 45 % (outside: 70 %) – adiabatic warming?



Conclusions (science & operations)

- Falcon measurements between April 19 and May 3, 2010: 2- μm-Lidar, in-situ aerosols, CO, O_3, SO_2, H_2O
- Particles sizes 10 nm - 30 μm age dependent (mainly silicate, ammonia sulfate, more Na, K than in Saharan dust),
- Mass loading (60 μg/m^3, Leipzig, 5 days) comparable to Saharan dust (< 0.2 mg/m^3)
- 200 km distance, 3-4 h age: 40 km wide, 2 km thick, 15 m/s, sharply edged, strong wet convective turbulence, well mixed?
- 450 km distance (same plume), 7 h age: at upper plume edge: 400- 3400 μg/m^3, no 2-DC probe particles, mass flux > 3000 kg/s, strong chemistry
- Lidar signal and FSSP-300 signal strongly dependent on refractive index, ash density, particle size spectrum 1- 50 μm

- Mid-European airspace closure justified until Sat. April 17; then ageing of ash load
- Keflavik/Iceland free of ash as predicted on April 19 - May 2
- Quality of forecasts reliable enough for aviation
- Future: Combination of models + lidar + satellite + in-situ
- Improved linking between operations and academia
- Continue operations of the DLR Falcon as Emergency Aircraft

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

Further Falcon Flights

May 9: Southern Germany: < 10 μg/m3; questionable air space closure

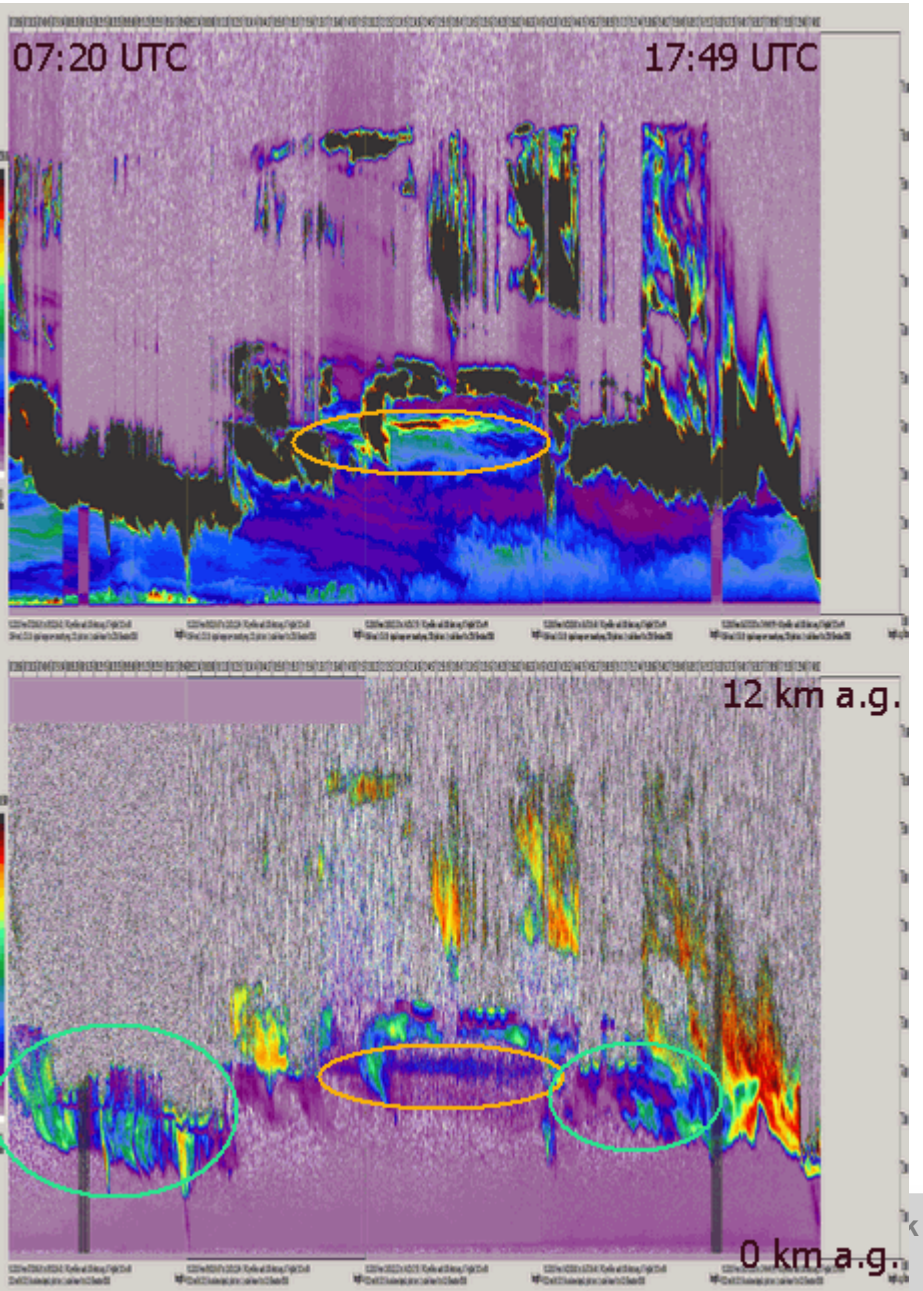
May 13: English Channel: MSG detected thin ash cloud < 30 μg/m3, without VAAC warning

May 16: England and North Sea: thick volcanic ash plume > 2000 μg/m3

May 17: North Sea VA 450 μg/m3, observed also by MSG and Lidar Cabauw

May 18: Thin ash cloud over Germany (Lidar Stuttgart)

DLR-Falcon flight over Southern Germany, May 9, 2010



mass loading below 10 μg/m3

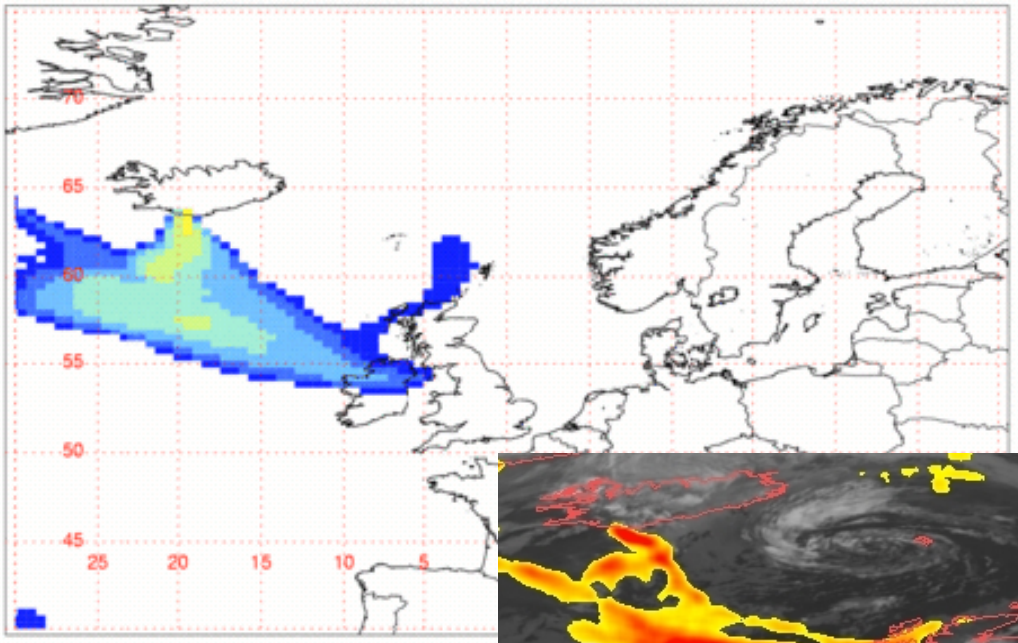
<- Measurements performed by the Met. Institute of the LMU Munich

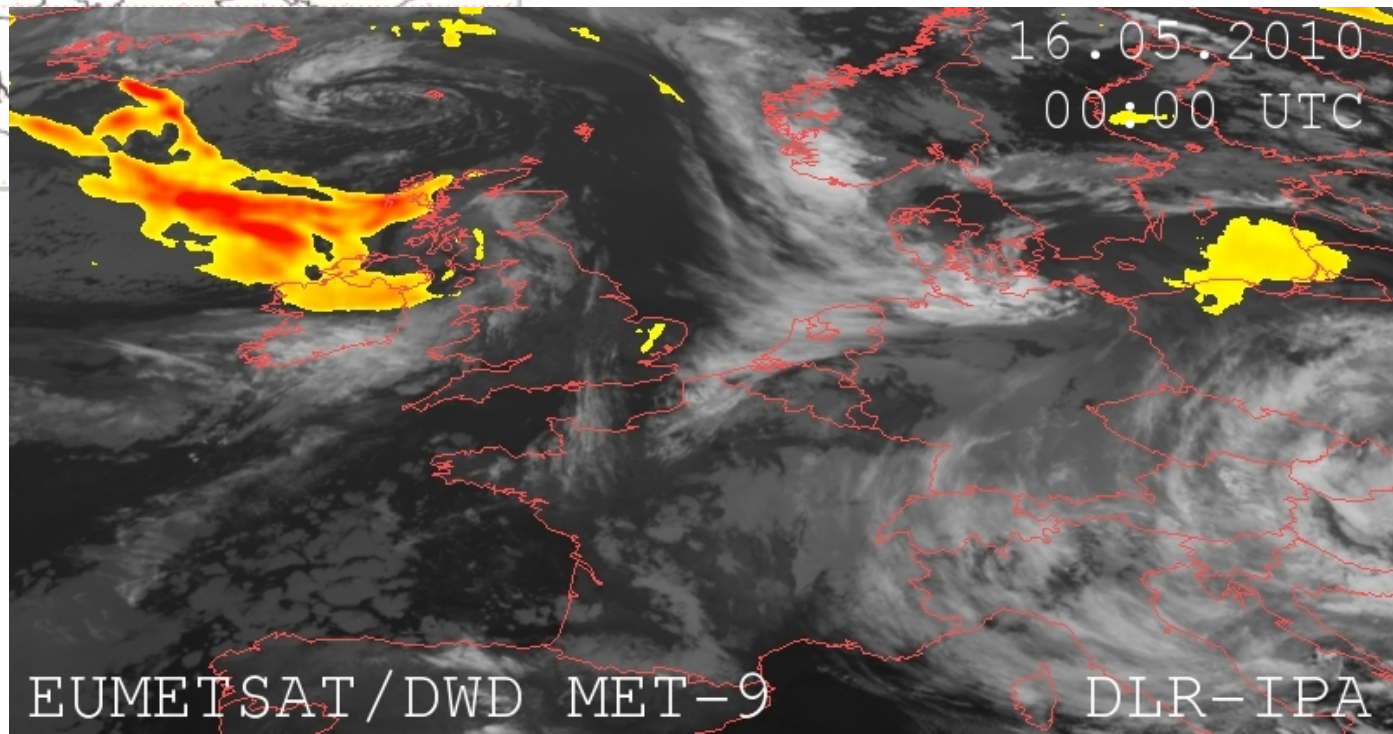
Flight level 000 to 200

England, May 16, 2010 0 UTC

Met Office

006 hr time averaged Air Concentration
From FL000 - FL200
Valid at 0000UTC 16/05/2010





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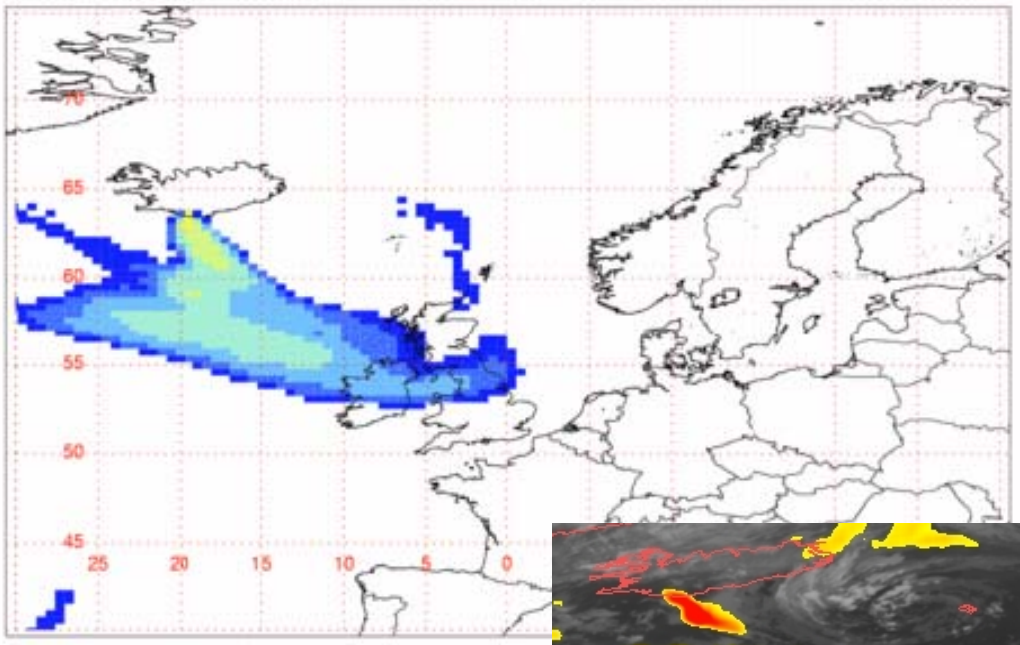
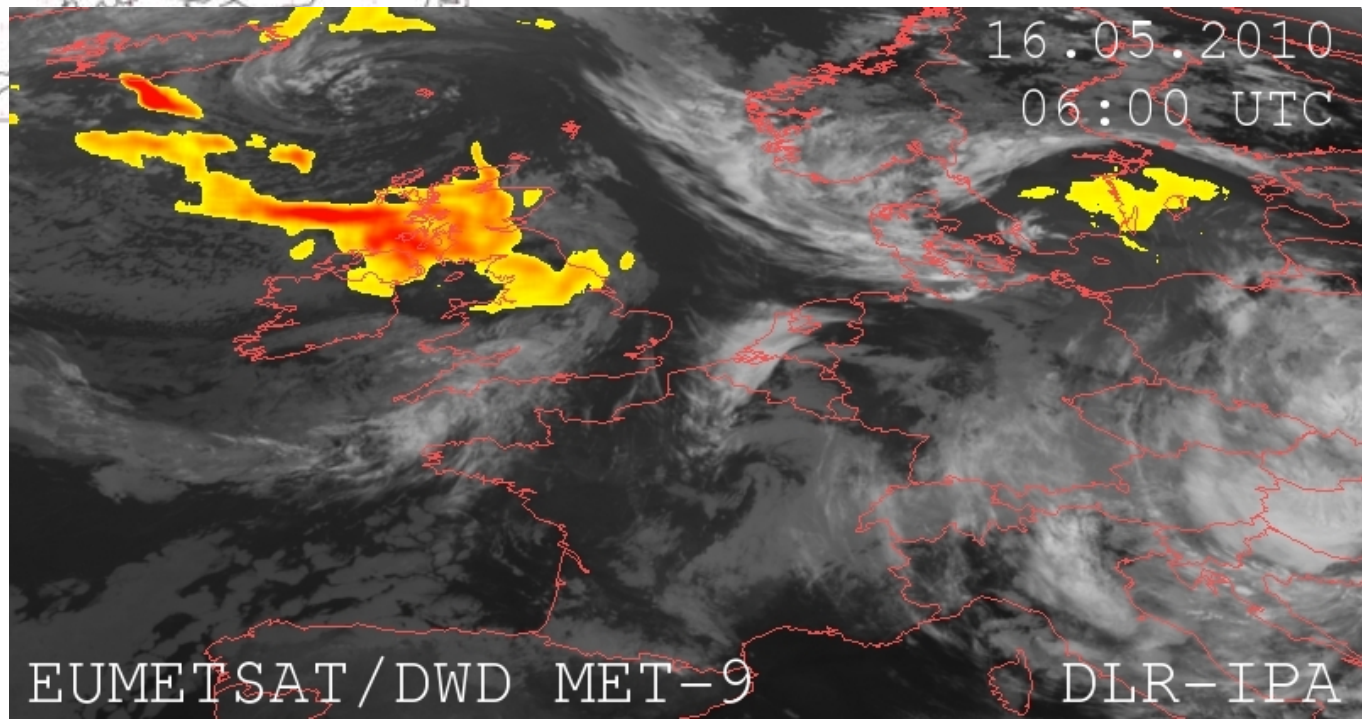
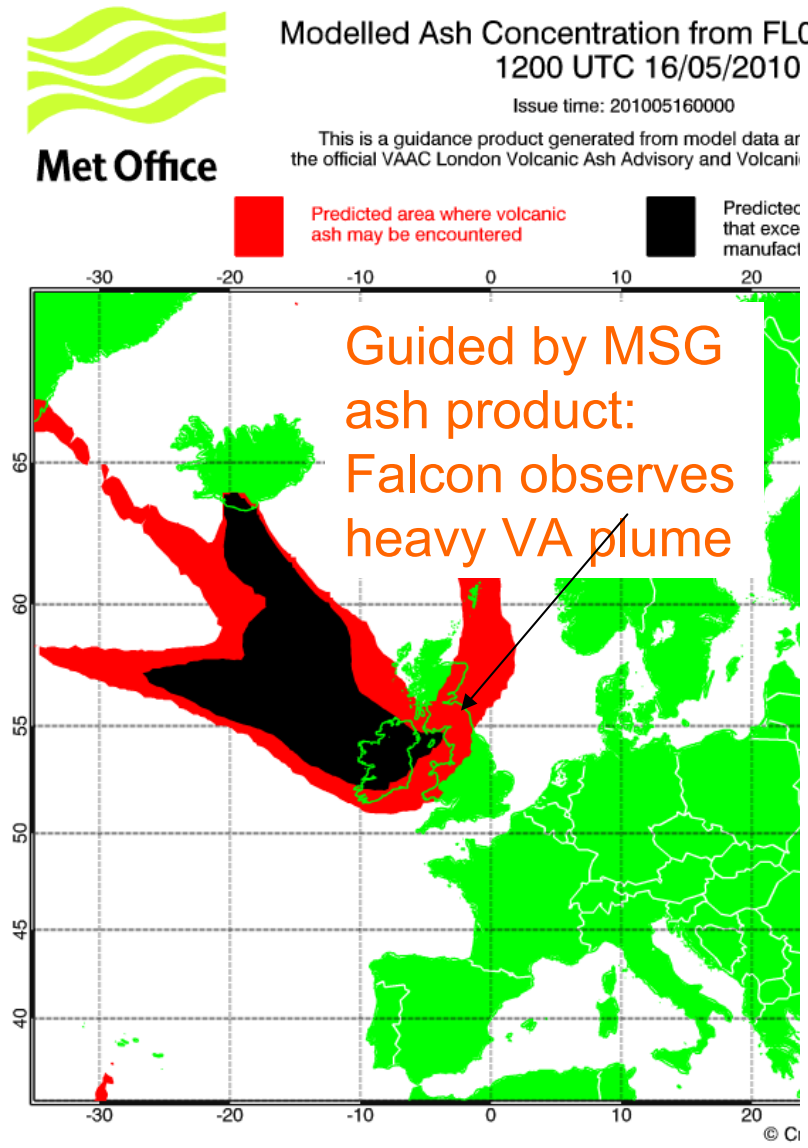
in der Helmholtz-Gemeinschaft

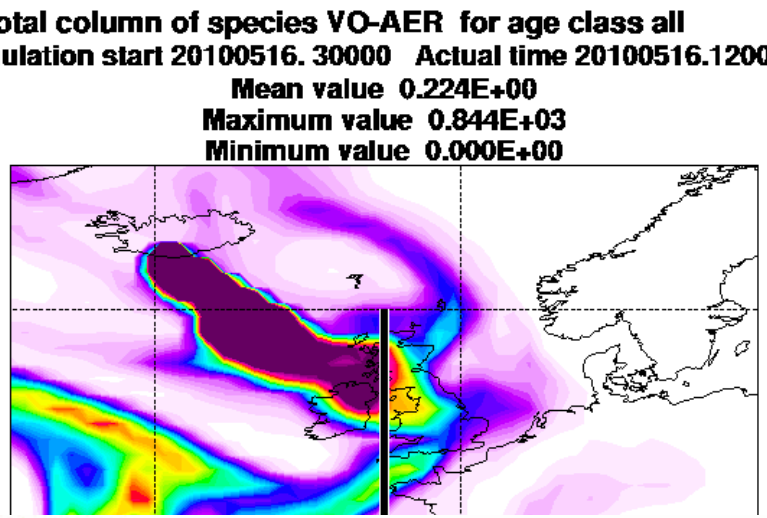
England, May 16, 2010 6 UTC

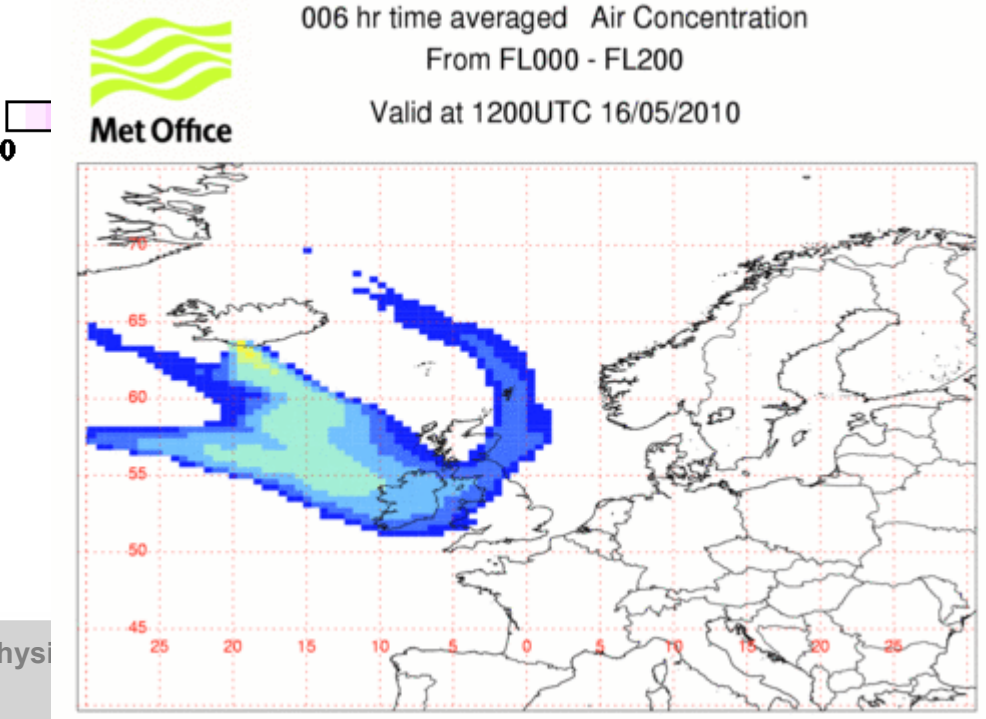




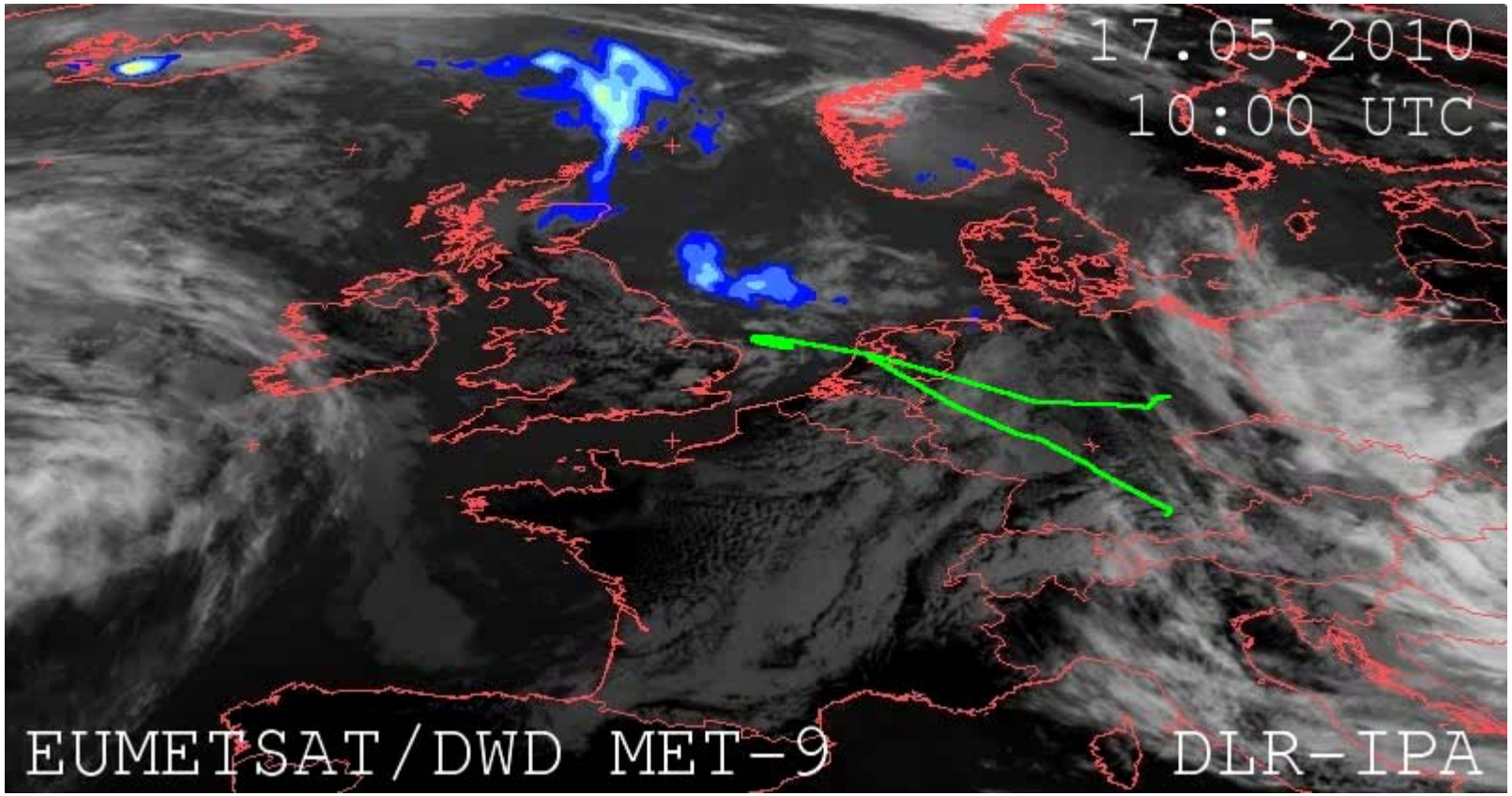
England, May 16, 2010 12 UTC







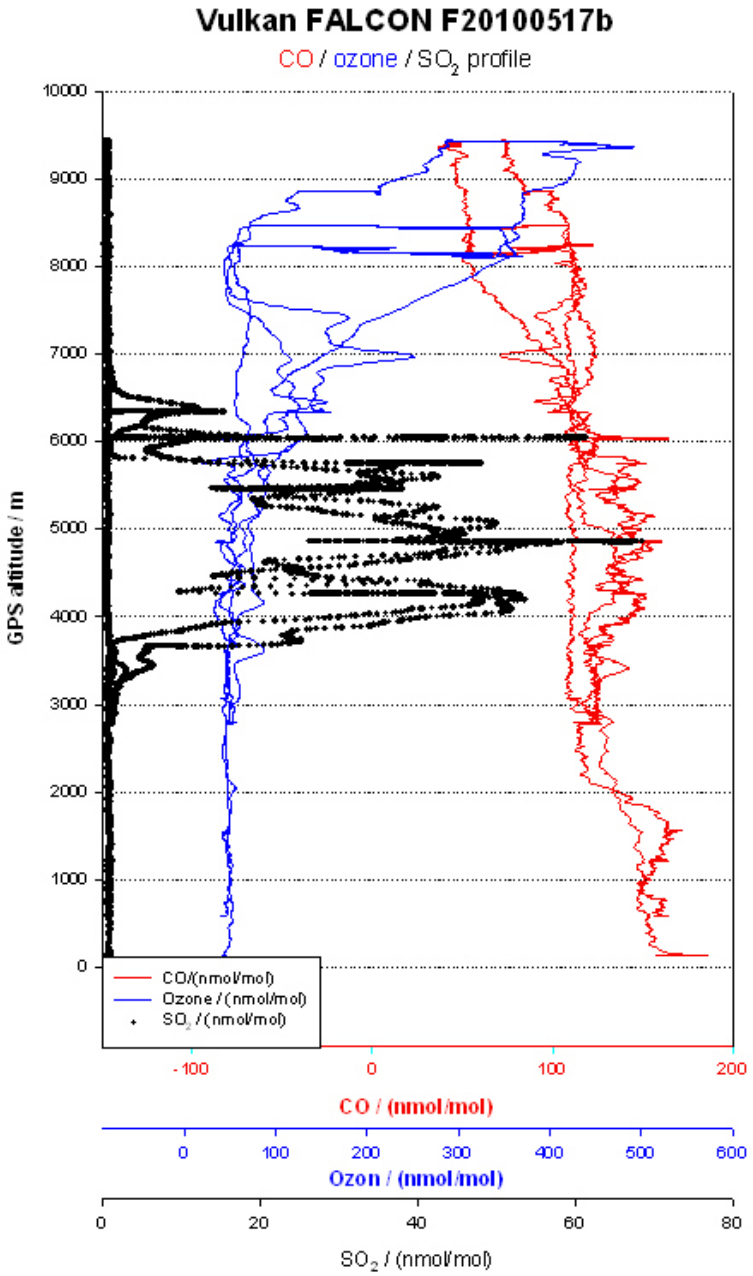
Satellite image with Falcon track, volcaon ash plume reaching Amsterdam at about 19:00 UTC



colours to compare approximately with VAAC predictions

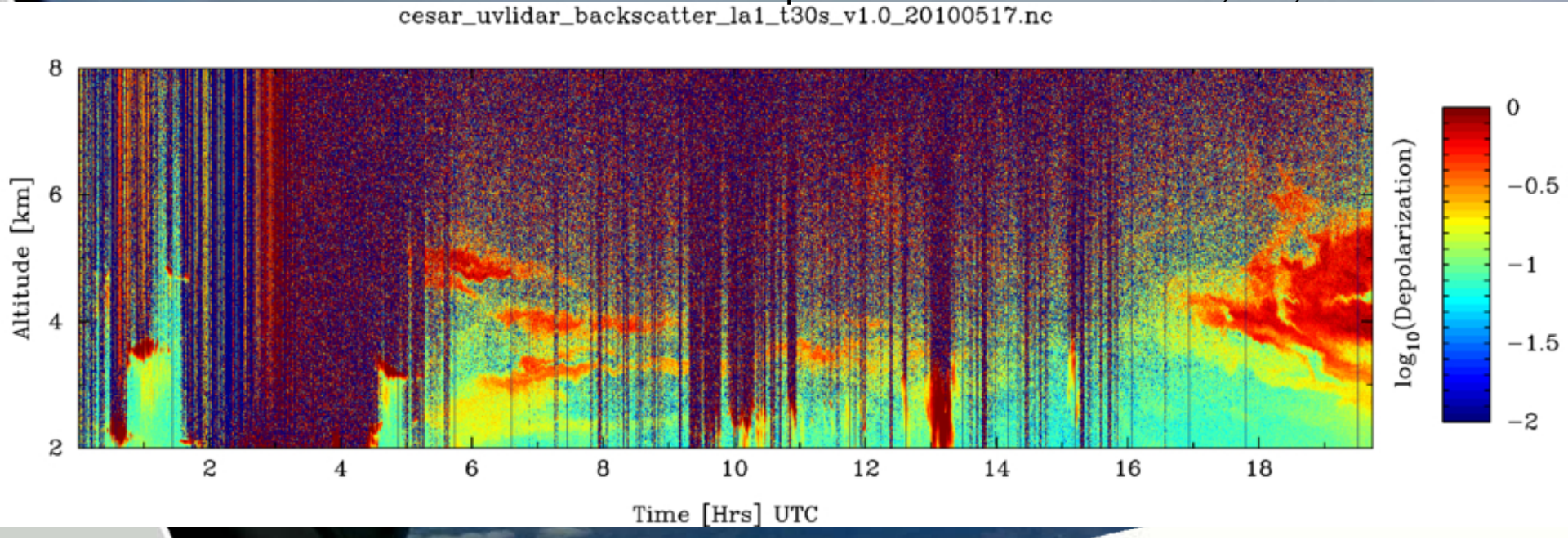
Vertical profiles SO2, CO, O3

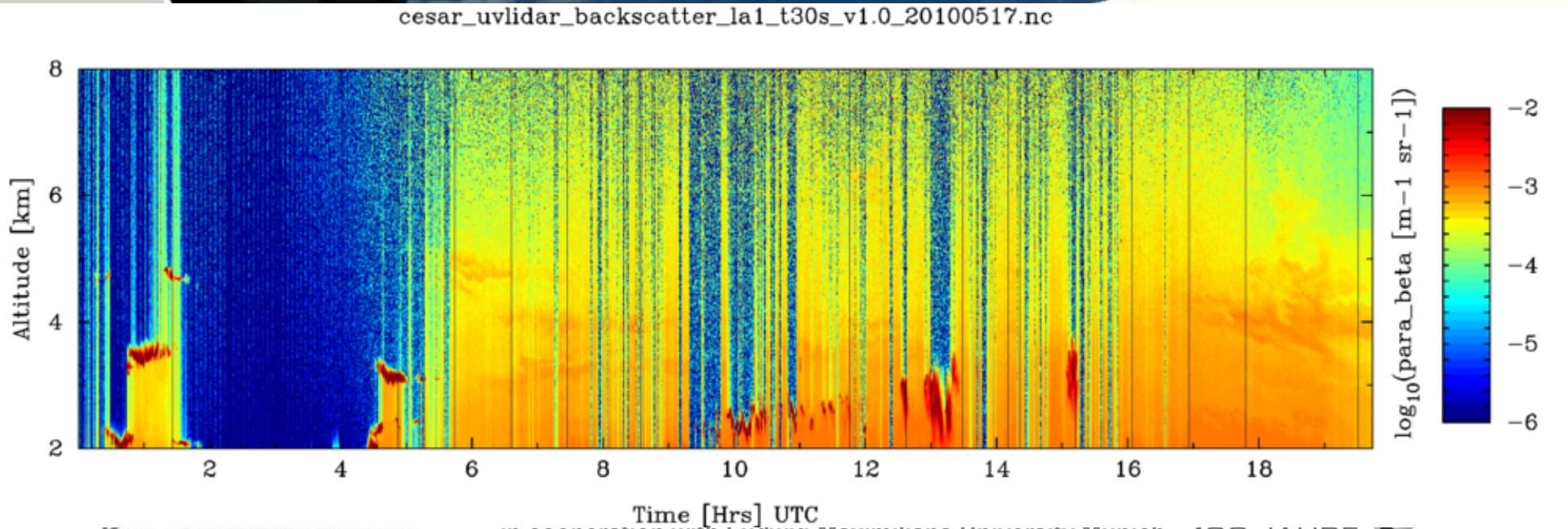
Institut für
Physik der Atmosphäre
Schlager, Lichtenstern, Scheibe, Stock



Particle size distribution; 0.1 to 25 μm diameter: derived mass concentration assuming refractive index 1.54+0i and density 3 g/cm³: **450 µg/m³** ± 50 %

UV LIDAR CABAUW: Falcon-traced ash plume arrived at Cabauw, NL, 16:30 UTC





Further Conclusions, after 5 weeks with 51.5 Falcon flight hours

- Falcon measurements between April 19 and May 18, 2010:
  2- μm-Lidar, in-situ aerosols, CO, O_3, SO_2, H_2O
- Falcon confirms MSG ash product at least qualitatively
- Further in-situ data for comparison to Lidar observations

- The set of flight paths data (waypoints versus time) are available on the internet with permit of BMVBS/DWD
- DLR offers comparison of Falcon in-situ (CO,O3, SO2, H2O, particles, mass concentration) and 2-um-Lidar data with any other available data. Contact via Ulrich Schuman

- Southern German airspace closure Sun. May 9, 6 days aged VA: questionable
- Closure over UK, May 16, 1-2 days aged plume: fully justified
- Fresh and heavy VA is well predictable - >3 days aged VA: far more difficult
- 1 hour of flight in VA ash of 450 um/m3: no Falcon engine problem detected
- Next: HSRL on HALO